SHOCK15-2015-000645

Abstract for an Invited Paper
for the SHOCK15 Meeting of
the American Physical Society

Probing Aluminum Reactions in Combustion and Explosion Via the Kinetic Isotope Effect

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The mechanism that controls the reaction speed of aluminum in explosion and combustion is poorly understood, and experimentally difficult to measure. Recently, work in our laboratory has demonstrated that during the combustion of nanoparticulate aluminum with H2O or D2O, different reaction rates due to the kinetic isotope effect are observed. This result is the first-ever observed kinetic isotope effect in a metal combustion reaction and verifies that chemical reaction kinetics play a major role in determining the global burning rate. During or shortly after a detonation, however, the reaction rates are dramatically faster and the physical mechanism controlling Al reaction is likely different than during combustion events. To utilize the kinetic isotope effect to probe Al reactions in detonation, formulations were produced that contain powdered Al in deuterated high explosives and high-fidelity detonation velocity were determined along with PDV measurements to observe early wall velocity expansion measurements. The JWL equation of state was solved to determine temperature, pressure and energies at specific time periods, in addition of Gurney energies, which enables the elucidation of Al reaction extent. By comparison of the Al oxidation with LiF, data indicate that Al oxidation occurs on an extremely fast time scale and isotope effects in both the HE detonation and post-detonation Al reactions are discussed.